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EFFECT OF DIFFERENT DENTURE BASE MATERIALS ON STRESSES TRANSMITTED TO SUPPORTING STRUCTURES OF IMPLANT-SUPPORTED MANDIBULAR OVERDENTURE

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ABSTRACT

Aim The purpose of this in vitro investigation was to assess the impact of mechanical loading on various denture materials on supporting structures.

Materials and methods: Two completely edentulous epoxy casts, four implant-retained overdentures were used in this study and divided into two groups; group (I): epoxy cast with two titanium implants and group; (II) two zirconia implants, each group is retaining a conventional acrylic overdenture and a flexible acrylic overdenture in place. The implants were positioned in the epoxy resin casts at the canine region with the aid of a surgical guide. To simulate the soft tissues, soft liner material was used at the distal extension area. Measuring the peri-implant strains during unilateral and bilateral loading was carried out using two linear strain gauges bonded at the buccal and lingual aspects of each cast at each implant.

Results: The flexible acrylic overdenture with titanium implants showed the highest strain values during bilateral loading, while the conventional acrylic overdenture with zirconia implants showed the lowest strain values. The conventional acrylic overdenture with zirconia implants showed the lowest strain values during unilateral loading, while the flexible overdenture with titanium implants demonstrated the highest strain values in the loading side.

Conclusion: It was discovered that, relative to the other materials, flexible overdentures held in place by titanium implants transmitted more occlusal stresses at the marginal bone area, within the confines of this in vitro investigation.

KEYWORDS: Zirconia, Titanium, strain, Flexible acrylic, implant overdenture.

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INTRODUCTION

Patients without teeth usually had problems with their mandibular denture's retention. It has been found that non-retentive denture concerns are significantly reduced when denture retention is based on implants. Potential treatment options depend on the amount of accessible bone and the number of implants inserted. An overdenture can only be supported by two implants in the mandible. The inter-foraminal area, which is divided into five equal columns of bone between the mental foramina, is where these implants must be placed. A and E are in the first premolar area of A, B, C, D, and E, while C is in the midline and B and D are in the canine area.[1]. According to Wolff's law, bone will be stimulated by load and adjust to it within physiological bounds [2]. Furthermore, it is true that bone density and strength decrease with decreased strain brought on by a lack of stimulation. Consequently, density and strength decrease after the implantation of an implant or prosthesis due to a phenomenon called stress shielding, which transfers forces from the crestal bone to them instead of the bone. The phenomenon of stress shielding is caused by a high difference modulus of elasticity. The elastic modulus of zirconia is 210 GPa, while that of titanium is 110 GPa. Human bone has an elastic modulus of 14 GPa. [3,4]. Traditional acrylic resin used in denture base fabrication has an elastic modulus of 1602 MPa. [5] although it is less for flexible acrylic resin than for conventional PMMA[6]. Strain gauges are tiny electric resistors that, when inserted into a slightly deformed object, change the resistance in their current. This makes it possible to calculate the strain around the implant. The electrical impulses are generated and then moved to a board for data capture, where a computer reads the signals[7]. The need for such a study raised from the issue of concentration of stresses due to uneven load distribution secondary to difference in modulus of elasticity between oral and dental structures[8] and difference between modulus of elasticity of different denture base materials [9].

The null hypothesis of the study is that there is no difference between titanium implants and zirconia implants retaining conventional acrylic and flexible acrylic overdentures.

MATERIALS AND METHODS

Two completely edentulous epoxy casts, total of four implant-rertained overdentures were used in this study and divided into two groups; group (I): epoxy cast with two titanium implants and group; (II) two zirconia implants, each group is retaining conventional acrylic overdenture and flexible acrylic overdentures.

Fabrication of the test model and overdentures:

For the study, clear epoxy resin casts were used. Using addition silicone rubber base, an impression of a fully edentulous mandibular ridge was made for the models. After the cast was poured, undesired undercuts were sealed off, and a silicone mold was made to ensure that the models' ridge and arch shapes would never change. The silicone mold was then prepared for the production of the model casts by applying a thin coating of Vaseline to it. This acts as a separating medium and make it easier to remove the epoxy model after it has hardened. A clear epoxy resin mixture prepared in compliance with the manufacturer's instructions was poured into the silicone mold. The identical steps were performed for the second cast. The stone cast was then sprayed with Occlutec spray and scanned using a desktop scanner (Medit t710). A digital wax-up prosthesis was placed over the surgical guide to correlate the implant locations with the canine region. [10] Figure **1**. A digital replica of the cast was used to create a surgical guide that ensures consistent implant positioning and parallelism. Figure **2** The surgical guide design was then printed using a clear acrylic resin 3D printer (Phrozen, Sonic mini 4k)[11]. Furthermore, the intended implant was chosen at every stage of the design process.

A digital replica of the titanium implant (Implant Direct, USA) was made with Solidworks SP5 software. Its dimensions, 11.5 mm in length and 3.7 mm in diameter, were the same as those of the titanium implant. **Figure 3**. Two identical one-piece zirconia implants were milled using a five-axis milling machine (ED5X, Emar Mills, Egypt). **Figure 4** so that their designs would be the same and the stress distribution would not be affected by a difference in implant design. [12]. After that, the implants were placed using the surgical guide.

To simulate the osseointegration process, a new mix of clear epoxy resin was used to fix the implants in their place after drilling and positioning of the implants. Then, to mimic the soft tissues, a 2 mm thick layer of soft liner material was placed at the distal extension.[13] **Figure 5.** In order to create a cast that would be used to fabricate an overdenture, the level of the occlusal plane was then adjusted to be two-thirds the height of the retromolar pad for each cast **Figure 6**. An impression was then taken using an additional silicone rubber base.

Strain gauge analysis

Fixation of strain gauges:

The strain in the epoxy resin can be measured with a strain gauge to get a sense of the stresses applied to the surrounding bone around the implants. Two linear strain gauges (KFG-1-120C1-11, Kyowa Electronic Instruments; Resistance 120.2 0.2, gauge length 1 mm, gauge factor 2.11 1.0%) were affixed close to the crest of the ridge at the buccal and lingual surfaces associated with each implant

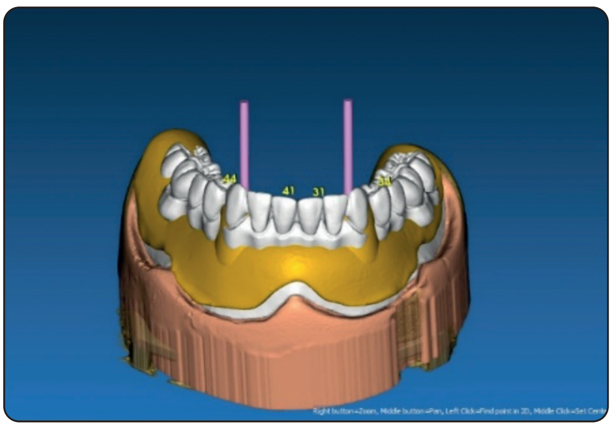

Fig. (1) Determining the positions of the implants.

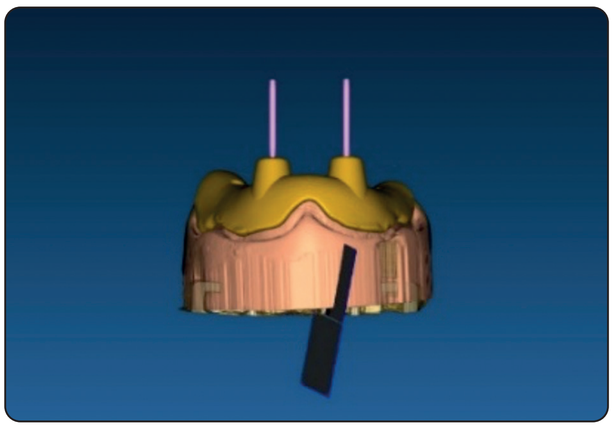

Fig. (2) Checking the parallelism of the implants.

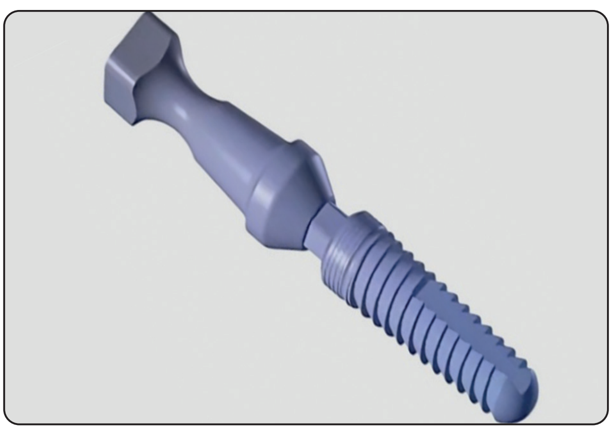

Fig. (3) Digital copy of the titanium implant.

Fig. (4) Milled Zirconia implant.

in order to measure the peri-implant strains during loading.[14] **Figure 7**. The long axis of each gauge was in line with the long axis of the implants. With the gauge wires, the lingual and buccal surfaces of the epoxy resin casts were securely taped. Each gauge was wired into a ¼ bridge on a Tinsley Precision Instrument, Model 8692, multichannel digital bridge amplifier.

Strain gauge measurements:

Using a universal loading machine (Lloyd LRX, Lloyd instruments), vertical static loads of 50 N were applied to the occlusal surface of the overdentures retained by implants. Loads were applied both unilaterally and bilaterally. A unilateral load was applied to the right side of the overdenture using an I-shaped load applicator, with the left side acting as the non-loading side and the right side as the loading side. **Figure 8**. Using a T-shaped load applicator, a bilateral load was applied to the left and right sides **Figure 9**. An occlusal notch in the central fossa of the first molar received both the unilateral and bilateral loads. The reason of using 50 N was that according to several studies it is the average biting force applied by denture wearers [15–17]. Strains around the implant at the buccal and lingual surfaces were measured in response to both unilateral and bilateral applied loads. The tests were performed three times for each cast, with a three-minute rest interval in between. Following that, the strain values were measured and exported for statistical analysis.

Fig. (5) Soft liner material used as a soft tissue mimic.

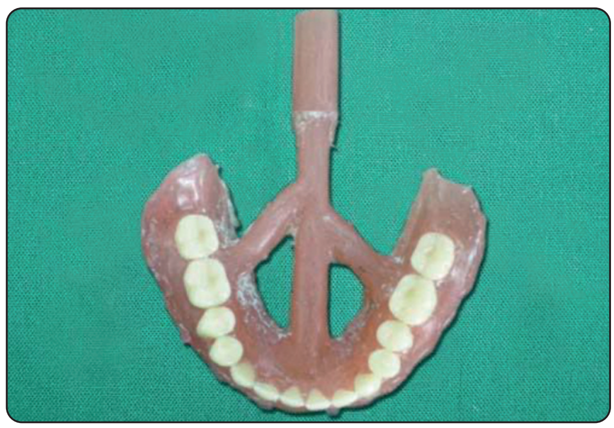

Fig. (6). Flexible acrylic overdenture

Fig. (7) Strain gauge fixation

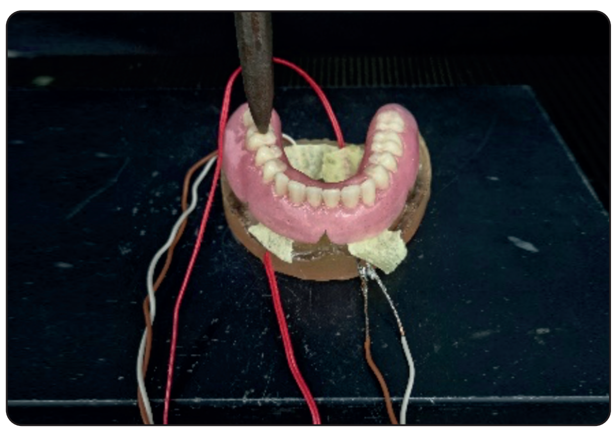

Fig. (8) Unilateral load application.

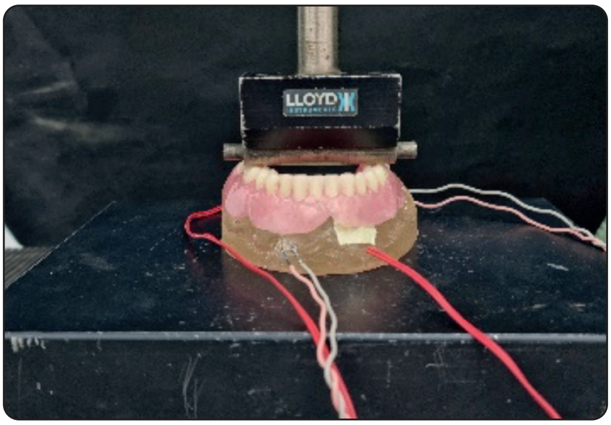

Fig. (9) Bilateral load application.

Statistical analysis

Data were statistically described in terms of mean ± standard deviation (± SD). Because the groups are large enough, comparison between the study groups was done using One Way Analysis of Variance (ANOVA) test with Tukey's posthoc multiple 2-group comparisons. Two-sided p values less than 0.05 was considered statistically significant. IBM SPSS (Statistical Package for the Social Science; IBM Corp, Armonk, NY, USA) release 22 for Microsoft Windows was used for all statistical analyses.

RESULTS

During bilateral load application

The strain values revealed a **significant difference** (p-value <0.001) between Acrylic OD on zirconia and Titanium implants. The Flexible Overdenture with titanium implants showed the highest values of stresses transmitted to supporting structures, as represented by strain values; the Acrylic Overdenture with zirconia implants showed the lowest values of strain values. Additionally, the Flexible OD with zirconia implants and the Flexible OD with Titanium implants showed **significant difference** in the values. (Table 1).

During unilateral load application

The strain values, at the loading side, showed **a non-significant difference** between loading side of Acrylic OD with zirconia and with titanium (p-value < 0.001), and **a highly significant difference** between Flexible OD with zirconia and titanium (p-value < 0.001) as well Table 2. The highest strain values at the loading side were recorded with Flexible OD with Zirconia implants. The lowest strain values at the loading side were recorded with Acrylic OD with titanium implants.

TABLE (1) Comparison of microstrains during bilateral loading.

Bilateral Loading	**(I)**	**(J)**	**Mean diff. (I-J)**	***p* value**
Overall	Conventional Acrylic with Titanium implants	Conventional Acrylic with Zirconia implants	29.987	0.003*
	Flexible acrylic with Titanium implants	Flexible acrylic with Zirconia implants	38.357	0.007*

Significance level p≤0.05, *significant

TABLE (2) Comparison of microstrains at the loading side during unilateral loading.

Loading side		Mean difference (I-J)	p-value
(I)	(II)		
Conventional Acrylic with Titanium implants	Conventional Acrylic with Zirconia implants	12.641	0.636
Flexible acrylic with Titanium implants	Flexible acrylic with Zirconia implants	14.273	0.879

Significance level p≤0.05, *significant

DISCUSSION

Different loads will be applied to the surrounding bone and the peri-implant area depending on the prosthesis type, loading type, and attachment type. Additionally, how much weight is transferred from the implants to the supporting structures depends on the number and distribution of implants[18]. According to a study, a rigid telescopic coping holding the overdenture in place would act as a firm, unbending lever, exerting a significant amount of force that would be transferred from the implant to the surrounding bone, even though telescopic attachment for a two-implant retained mandibular overdenture has a long history of clinical success. [16,19]. The study's findings showed that during bilateral load application, the lingual surface of the non-metallic implants showed more strain than the buccal side. This can be explained by the resilience of the mucosal mimic causing the distal saddles of the denture to cantilever when a load is applied occlusally, creating a lever action with the lingual side functioning as a fulcrum[20]. The implant overdenture tends to hinge and rotate when posterior loading is applied to anteriorly positioned implants (in the inter-foraminal area). The findings showed that zirconia implants in the canine area showed the lowest peri-implant strain values when compared to titanium implants. The higher elastic modulus of zirconia might help to explain this [3,21], providing the highest degree of stress shielding for the crestal part. Among the materials tested, the use of that bone would therefore result in the highest marginal bone loss because of the atrophy caused by lack of use. However, the flexible acrylic overdenture supported by titanium implants showed the highest overall strain values. These results are explained by the lower elastic modulus of titanium material (compared to the modulus of elasticity of zirconia) and the flexibility of flexible acrylic, which brings its value closer to the surrounding structures[22]. On the other hand, the traditional acrylic overdenture secured by zirconia implants showed low strain values, indicating the material's remarkably high modulus of elasticity and stiffness's stress-shielding effect[23]. The loading side strain values of titanium implants showed a notable distinction between the flexible acrylic overdenture and the traditional acrylic overdenture with titanium. The discrepancy in the stress shielding effect was ascribed to the stiffness and elastic modulus of the overdenture. [14,21].

The study experienced a number of drawbacks, including not using different types of epoxy resin to simulate different bone quality and not measuring strain at the mesial and distal peri-implant sites due to limited area, which would have recorded strain over wide area rather than at the crestal region around the neck of the implant. Additionally, not applying dynamic loading to mimic the masticatory process could cause the occlusal forces to change and cause a different pattern of peri-implant stresses. Similar to earlier in vitro research, the strain gauge analysis data is usually only descriptive because the characteristics of epoxy resin cannot accurately mimic the intricate structure of living bone.

Other studies discussed similar issues regarding modulus of elasticity of different denture base materials showing that the flexible acrylic resin denture base transfers more stresses that the conventional acrylic denture base[5,9]. Also other studies mentioned the difference between modulus of elasticity between Titanium implants and zirconia implants and their effect on stresses distribution to surrounding oral structures, revealing similar results to our findings [8,24].

Though, various simulations presenting different bone thicknesses and implant designs are still needed to provide a better understanding of the biomechanics of zirconia implants.

CONCLUSION

Given the limitations of this in vitro investigation, the following conclusion can be drawn:

Although not exhibiting the lowest strain values among the materials compared, flexible acrylic overdentures with zirconia implants showed low strain levels, indicating their stress-shielding effect. Flexible acrylic overdentures with titanium implants showed the highest levels of peri-implant strain when compared to conventional acrylic overdentures with both implants and flexible acrylic overdentures with implants. This made it possible to avoid the problem with stress shielding those other materials brought about.

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